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A MULTIPLE-TASK PERFORMANCE BATTERY PRESENTED ON A CRT

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A minicomputer controlled battery of tasks is provided which can be presented individually or in combination on a single peripheral device, a cathode ray tube (CRT), and which uses the accompanying keyboard as the operator's console. The battery is composed of the following five tasks which represent major dimensions of complex human performance: ~~1)~~ probability monitoring, ~~2)~~ arithmetic operations, ~~3)~~ target identification, ~~4)~~ warning light monitoring, and ~~5)~~ blinking light monitoring. This system shows that a computer-based

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CRT display facility can provide, in a single instrumentation complex, all of the advantages of the several separate packages currently found in performance assessment batteries, and more importantly, add a flexibility of input and output control that has never before been possible.

This paper describes a minicomputer-controlled battery of tasks which can be presented singly or severally on a single peripheral device, a cathode ray tube (CRT), and which uses the accompanying keyboard as a response manipulandum. This multiple-task performance battery is similar to a performance battery originally proposed by Patton and his associates (Patton, 1977), and it has been used extensively over the past decade or more as the principle performance assessment tool within a variety of research settings and applications (Adams and Chiles, 1960, 1961; Alluisi and Chiles, 1967; Alluisi, Chiles, and Hall, 1964; Alluisi, Chiles, Hall, and Hawkes, 1963; Alluisi, Hall, and Chiles, 1962; Alluisi, Thurmond, and Coates, 1971; Chiles, Alluisi, and Adams, 1968; Morgan and Coates, 1974; Morgan, Brown, and Alluisi, 1970; Morgan, Brown, Coates, and Alluisi, 1975; Thurmond, Alluisi, and Coates, 1971). There is more than one version of the basic multiple-task performance battery, and the model for the development of the computerized battery was taken from the version presented in Morgan and Alluisi (1972), reflecting a "synthetic work" methodology, but eliminating the "code-lock" task.

A diagrammatic representation of the 20 cm x 25 cm CRT displaying the five individual tasks comprising the battery is presented in Figure 1.

Insert Figure 1 About Here

The figure is proportionally representative of the configuration of the tasks as observed by an operator, and the characters and symbols are almost identical to those displayed by the CRT.

The first task, probability monitoring, is displayed across the top of the screen. On each of four separate and independent 6-position scales,

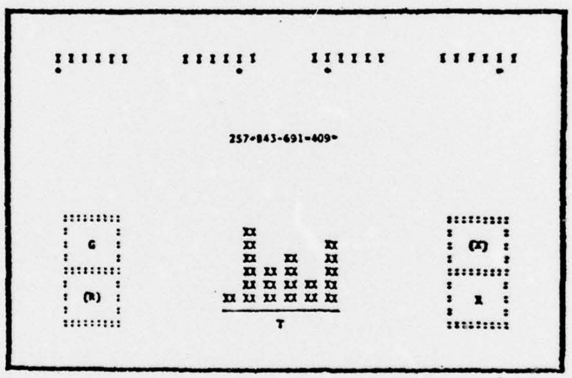

Figure 1. A diagrammatic representation of the cathode ray tube (CRT) displaying the five individual tasks comprising the battery. Letters in parentheses represent alternative states of respective tasks.

represented by the four clusters of capital Is, an asterisk pointer exchanges position twice per sec such that each scale position is struck with equal frequency over many successive exchanges, *e.g.*, 30. At unsystematic intervals under such baseline conditions, a bias (*i.e.*, signal) occurs such that 75 per cent of the pointer values are located either on the left (left signal) or on the right (right signal) three positions of a scale. A left or right signal is presented for 2 min, and failure to detect it during this interval causes the biased scale to return automatically to the baseline state. If the operator detects the signal, the scale immediately returns to the baseline state. Left and right signals and one of four baseline intersignal intervals (*e.g.*, 30, 60, 90, and 120 sec) are presented in an unsystematic order. Since each scale is independent with respect to its parameters of operation, it is possible for either a single signal to be present among the four scales or for all scales to have signals simultaneously. All other combinations of signal and baseline states are also possible, and they depend, at least in part, on the operator's accuracy and his latency in detecting the presence of a signal on any given scale.

The second task, *arithmetic operations*, is presented below the probability monitoring task. An arithmetic problem composed of three 3-digit numbers is presented on the screen. The problems are generated by unsystematic selection of consecutive digits with the limitation that answers must be 3-digit positive numbers. The solution requires summing the first two numbers and subtracting the third number from the sum. Calculations are performed without paper and pencil or other aids, and operators typically solve problems digit by digit. The operator enters an answer after the "=" sign, the hundreds digit being entered first, the tens digit second, and

the units digit third. The operator is allowed to change an answer, but once it is "locked in" by him for evaluation, producing an asterisk to the right of the answer, no further changes can be made. New problems are presented automatically every 40 sec, irrespective of the operator's latency of entering and "locking in" an answer or of his accuracy.

The third task, target identification, is presented below the arithmetic operations task. An original histogram is presented within a 6 x 6 element matrix with its base at 6 o'clock and with no bar lengths repeated. This "target" histogram is erased, and two "matching" histograms are presented and erased successively. The matching histograms appear rotated with bases at 9 o'clock, 12 o'clock, or 3 o'clock. One of the two matching histograms, or neither of them, may duplicate the target histogram. For each histogram in a series, a line is presented at the 6 o'clock position below which is a "T," "1," or "2," according to which histogram in the series is currently displayed, the target (T) or the first (1) or the second (2) matching histogram. When the second matching histogram has been erased, the operator indicates whether the first, second, or neither of the matching histograms was identical to the target. Consecutive bar lengths are generated by unsystematic selection, as are the matching rotations and the match itself, i.e., neither, first, or second. Each histogram is presented for 5 sec, the interval between successive histograms in a series is 15 sec, and the interval between a series of histograms is 25 sec. The operator, then, has 25 sec in which to enter an answer following erasure of the second matching histogram.

The fourth task, warning light monitoring, is presented to the left of the target identification task. Within the two vertically arrayed displays,

a "safety-state" character (G) is extinguished in the upper display, and an "alarm-state" character (R) is illuminated in the lower display. Whenever the operator detects the alarm state during its 5-sec duration, the "R" is erased and the "G" reappears. If the operator fails to detect the alarm state, the "R" is erased and the "G" reappears automatically at the end of the 5-sec interval. One of four safety-state durations (e.g., 15, 30, 45, and 60 sec) is selected in an unsystematic order. The parameters associated with this task require rapid response to changes of state, and the frequency of such changes is relatively high.

The fifth task, blinking light monitoring, is presented to the right of the target identification task. Under baseline, an "X" changes position between two vertically arrayed displays at a rate of once per sec. A signal occurs when the "X" becomes fixed and flashes in either the upper or lower display. If the operator detects the signal during its 30-sec duration, the task immediately returns to baseline. If the operator fails to detect the signal, the task automatically returns to baseline at the end of the 30-sec interval. One of four baseline durations (e.g., 40, 50, 60, and 70 sec) and the location of a signal, i.e., upper or lower display, are selected in an unsystematic order. This task, then, is relatively intermediate in the frequency of its signals and in the necessary alacrity of response for detection.

A diagrammatic representation of the keyboard manipulandum is presented in Figure 2. The keys on which numbers and/or letters appear are those

Insert Figure 2 About Here

used to perform the tasks, and they are labeled with marking tape for

Figure 2. A diagrammatic representation of the keyboard manipulandum.

accentuation. The first row from the top contains the numbers that are entered as solutions to the arithmetic operations task. The "CR" key in the second row "locks in" the answer, and the "RB" key in the third row erases an answer which has not yet been "locked in." In row three, the probability monitoring task uses keys "D1," "D2," "D3," and "D4" to indicate the presence of a left <u>or</u> right bias signal on each of the four scales, from left to right, respectively. Additionally in row three, the target identification task uses keys "0," "1," and "2" to indicate, respectively, (a) neither matching histogram, (b) the first matching histogram, or (c) the second matching histogram. In row four, the warning light monitoring task uses the "R" key to indicate the presence of an alarm state, and the blinking light monitoring task uses the "X" key to indicate the presence of a signal. The positions of the task keys on the keyboard were chosen for convenience of operation, and remaining unlabeled keys are inert.

The software for the performance battery resides within a PDP8/E minicomputer.[2] The battery will operate with 12K of memory if software random number generators are used and with larger blocks of memory if tables of random numbers are used. The author has a preference for a table of random numbers, although operators have reported recognizing repeated arithmetic problems after several thousand presentations of problems generated from a 4K table of numbers taken from Edwards (1950).

The performance battery is displayed on a VT05 alphanumeric display terminal. Although the upper limit of speed of transmitting information to this unit is only 2400 baud, this baud rate is adequate for most tasks to operate smoothly, without noticeable hesitations or interruptions. The single exception is the target identification task which requires 1.0 sec

to "build" a histogram. To avoid interference with other tasks, only one matrix element, i.e., two adjacent Xs., is presented at a time, and software serves other tasks prior to presenting successive elements. For a battery of this nature, 2400 baud is rapidly consumed by cursor addressing and other commands which require nul "filler" characters to be transmitted to the unit for proper operation.

The software was composed with programs residing on the OS/8 operating system, version III, in conjunction with two TU56DECtape units. The interrupt mode, rather than status check, was used to permit almost simultaneous operation of the VT05 and a LA36 Decwriter II. The Decwriter unit serves for data output, and five of its keyboard keys are dedicated as "on-off" switches for the five tasks in the battery. Switching on a task causes its corresponding display to be presented, e.g., the four clusters of Is on the probability monitoring task, and switching off a task causes erasure of all its characters and the display itself, e.g., the Xs and the boxed displays on the blinking light monitoring task. Two 12-channel buffered I/O interfaces are used (1) to illuminate indicator lights associated with each task and with the signals presented on the probability monitoring, warning light monitoring, and blinking light monitoring tasks, and (2) to operate an "add-subtract" counter incrementing for correct responding on tasks and diminishing for false alarms on the probability monitoring, warning light monitoring, and blinking light monitoring tasks. Finally, a real-time programmable clock, continuously interrupting at a fixed rate, is used to perform the many timing requirements in the program.

The software is structured within a foreground/background format as described in Introduction to Programming (DEC, 1975). Foreground is dedicated

to servicing devices requesting an interrupt, i.e., (1) the VT05 screen and keyboard, (2) the Decwriter printer and keyboard, and (3) the real-time programmable clock. Additionally, whenever the clock initiates an interrupt, flags, i.e., memory locations in a 0 or 1 state, are tested to determine which of the many timing subroutines in the program require servicing. Background continuously tests flags which when raised, i.e., in the 1 state, cause associated task or data subroutines to be serviced, output buffers to be loaded with information, and interrupt requests to be initiated to accomplish the transfer of information from the output buffer to the screen or to the Decwriter. For example, a foreground subroutine timing the duration of the asterisks on the probability monitoring task raises a flag in background when the duration has expired. Background detects this flag, and, in response, services subroutines which determine the next pointer positions. An output buffer is then loaded with information which when transmitted to the CRT causes erasure of the pointer line and printing of the new scale values. The transmittal of information is accomplished in the interrupt mode which is initiated by background, after the output buffer has been loaded, with a nul TLS instruction device coded for the VT05. Other background flags associated with the CRT screen are not tested until the transfer of information has been completed. Finally, the flags in background are arranged in an order of priority such that rapidly executed tasks, e.g., probability monitoring, are serviced before slowly executed tasks, e.g., warning light monitoring.

Data is output to the Decwriter at regular intervals, e.g., every 5 min, and the following information is presented for each task: (1) probability monitoring: hits (H), misses (M), false alarms (F), and the mean

latency, in sec, for hits (L); (2) arithmetic operations: right (R), wrong (W), misses, and mean latency for right; (3) target identification: right, wrong, and misses; (4) warning light monitoring: hits, misses, false alarms, and mean latency for hits; and (5) blinking light monitoring: hits, misses, false alarms, and mean latency for hits. Figure 3 presents a reconstruction

Insert Figure 3 About Here

of a performance record over the initial 30 min by an operator who had almost 50 hr practice on the battery with all five tasks operating simultaneously with the parameters previously presented. As is typical for a practiced operator, all five tasks are usually engaged. Operators customarily adopt a serial strategy to the battery, solving or checking one task, then scanning successive tasks. The data in Figure 3 also show that errorless performance during any given 5-min interval was rare, even for this practiced operator. This suggests that operation of the battery continues to challange an operator when all five tasks are presented simultaneously. However, the parameters of a given task can be easily adjusted, as can the number and combinations of tasks presented, to yield a practiced level of performance accuracy and sensitivity that is required for particular experimental objectives.

In summary, a CRT display terminal was capable of reproducing the essential features of a multiple-task performance battery having wide application as a performance assessment tool. Additionally, its accompanying keyboard served as the sole response manipulandum for operating the individual tasks. Such use of a CRT facility is consistent with the proposal of Mayzner (1968) who suggested the potential power of computer technology

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P H0002M0003F0001L058.2 A R0006W0000M0001L016.6 T R0004W0000M0001 W H0015M0002F0001L000.8 X H0006M0000F0000L003.4
P H0002M0004F0001L082.5 A R0005W0000M0000L011.3 T R0005W0000M0000 W H0012M0000F0000L000.8 X H0007M0000F0001L002.3
P H0004M0004F0001L045.9 A R0005W0002M0000L010.3 T R0004W0000M0000 W H0015M0000F0000L000.8 X H0005M0000F0000L002.1
P H0005M0002F0000L050.3 A R0005W0001M0000L012.1 T R0004W0001M0000 W H0012M0000F0000L000.7 X H0005M0000F0000L003.1
P H0002M0003F0000L045.9 A R0008W0000M0000L014.3 T R0004W0001M0000 W H0016M0000F0000L000.8 X H0003M0000F0000L003.3
P H0002M0005F0000L080.6 A R0006W0000M0000L014.9 T R0004W0000M0000 W H0012M0000F0000L000.8 X H0009M0000F0001L003.1
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Figure 3. A reconstruction of a performance record. Data entries for the tasks follow the identifying capital letters: P=probability monitoring, A=arithmetic operations, T=target identification, W=warning light monitoring, and X=blinking light monitoring. See text for description of data entries.

for presenting tasks of relevance to psychological research in the areas of visual perception, learning, and memory, at the least. The present system affirms the view of Mayzner who concluded "...that a computer-based CRT display facility can often provide, in a single instrumentation complex, all of the advantages of the several separate packages that currently are found in present day experimental psychology laboratories, and more importantly, add a flexibility of input and output control that has never before been possible" (Mayzner, 1968, p. 41).

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FOOTNOTES

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2. All referenced hardware devices and operating systems were obtained from Digital Equipment Corporation.

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